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Water Consumed by a Case Automatic Engine Direct Connected to a Crocker-Wheeler Dynamo.

J. Lawrence Hagy

June 19, 1899.

Hagy '99.
Case Engine.
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Water Consumption by a Case Automatic Engine Direct Connected to a Crocker-Wheeler Dynamo.

One of the most important things in the determination of the value of a steam engine is the amount of water consumed in a given time for each unit of output.

The output may be expressed in brake horsepower as in the case of a single engine or it may be expressed in watts or perhaps better in kilowatts when the engine is connected directly to a dynamo.

A steam engine is an apparatus for the conversion of heat energy into mechanical en-

gy by means of the expansion of water.

A dynamo, or more accurately a dynamo-electric-machine is one for the conversion of mechanical energy into electrical energy by means of magneto electric induction.

Dynamos are divided with respect to their number of pole-pieces into three classes viz.

1. Unipolar dynamos, or those having one pole,
2. Bipolar dynamos, or those having two poles, and
3. Multipolar dynamos, or those having more than two poles.

They are used for three principal purposes

1. Incandescent lighting

2. Arc lighting and

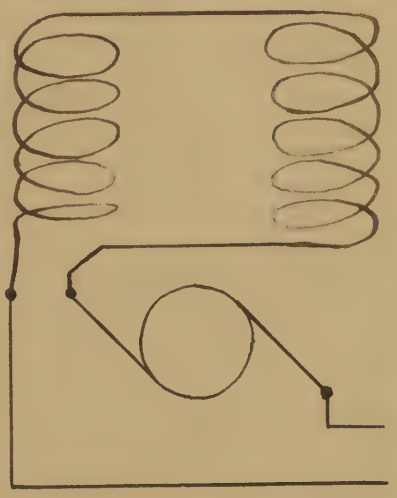
3. For the distribution of power.

The two principal divisions in the classification of dynamos are

1. Direct current dynamos
2. Alternating " "

Direct current dynamos may be either series wound, shunt wound, or compound wound.

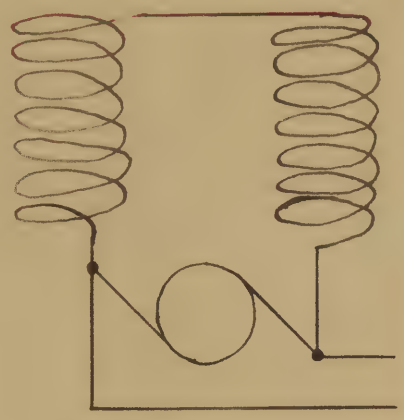
In series machines the coils of the field magnets are wound with a few turns of thick insulated wire, joined in series with the armature and external circuit.



SERIES MACHINE.

The shunt wound dynamo differs from the series wound ma-

chine in that an independent circuit, composed of many turns of fine insulated wire, is used for exciting the field magnets.



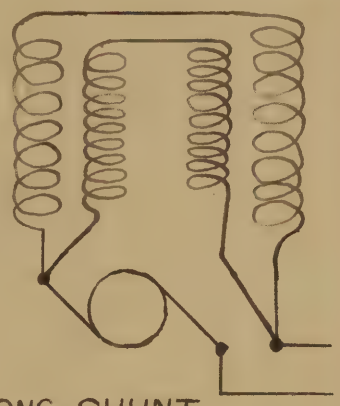
SHUNT MACHINE.

The compound wound dynamo is the shunt and series machine in one. The field magnets are wound with two separate coils, one of which is in series with the armature and external circuit, and the other in shunt with the armature. On open circuit it is shunt excited, while on full load the series coil has its greatest effect.

Compound wound machines have two methods of connecting,

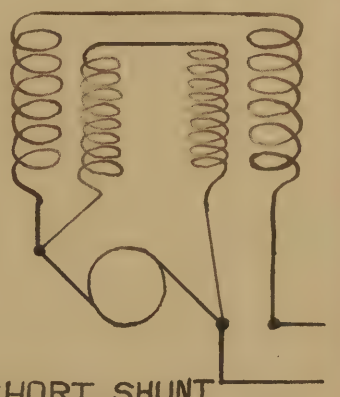
namely, long shunt, and short shunt.

In the long shunt connection the shunt winding is connected to the terminals of the machine and hence outside the series winding. When the line switch is open the electromotive force is that due to the shunt field, plus a small amount due to the series field.



LONG SHUNT COMPOUND DYNAMO

In the short shunt connection the shunt winding excludes the series winding and the latter is entirely idle on open circuit.



SHORT SHUNT COMPOUND DYNAMO

The compound wound dynamo

is used for the purpose of maintaining a constant pressure in incandescent lighting. The winding is so arranged, that a specific number of revolutions of the armature — neither more nor less — are necessary to secure and maintain the requisite electromotive force. Variation from the required number of revolutions is liable to result in unsatisfactory working of the dynamo, and may result in damage to it.

Constant speed is of prime importance and essential to the successful operation of compound machines. High speed engines, having automatic regulation and constant speed, are the most

satisfactory for this purpose.

In these engines the cylinder volume may be small, because it is filled oftener. This means an engine light in weight. The short length of cylinder means a small crank arm and a short connecting-rod, and therefore, an engine short in length.

When the engine makes a high number of revolutions per minute, each revolution is performed in a fraction of a second, and consequently, any variation in the effort or resistance is less noticeable as compared with the mean effort of any one minute.

When we speak of water

consumption by an engine we mean the amount of water used by or passing through the cylinder of the engine in the form of steam, and may be expressed either in pounds of steam of the quality actually supplied to the engine, or its equivalent in pounds of dry saturated steam.

There are two conditions of steam

1. Saturated and
2. Superheated

Saturated steam of any pressure is at its lowest temperature and possesses the least specific volume and greatest density corresponding with that pressure. It may be either wet

or dry.

Steam is said to be superheated when heat is added to it after it reaches the saturated condition. It behaves like a perfect gas in every respect. Its temperature is higher, its specific volume greater, and its density less than that of saturated steam of the same pressure. The excess of temperature above that of dry saturated steam is called the degree of superheat.

The quality of steam is expressed as the percentage (by weight) of dry saturated steam in a mixture of steam and water. It is determined by means of some form of calor-

imeter.

There are three processes for determining the amount of moisture in steam, all of which are included under the head of calorimetry

1. Calorimetry proper
2. Mechanical separation
3. Chemical

In the first process the heat actually existing in a pound of the steam used is compared with that existing in a pound of dry and saturated steam of the same pressure.

In the second process the water separated from the steam is weighed.

In the third process a

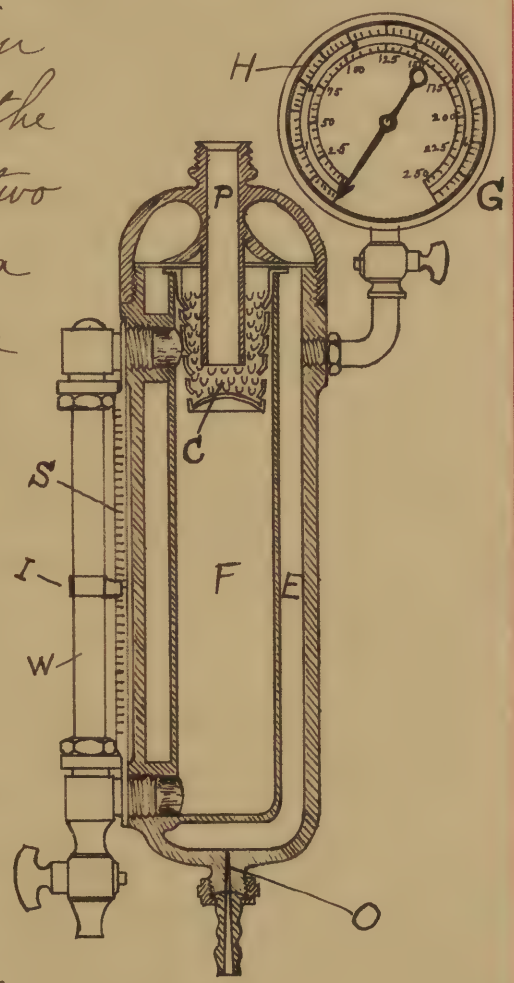
salt is introduced into the boiler. This salt is absorbed only by the steam containing moisture and the quality of the steam is determined by the ratio of the salt in the steam to the salt contained in an equal weight of water drawn from the boiler.

Calorimeters are classed as follows:-

1. Condensing
2. Superheating
3. Separating

The one used on this occasion was the Carpenter Separating Calorimeter, invented by Professor R. C. Carpenter of Sibley College, Cornell University, and shown in the accompanying sketch.

This instrument comes under the head of the third class. It consists of two vessels, one inside of the other. The outer vessel is cast in one piece with the inner vessel in two places in such a manner as to leave a space, which, when filled with steam, acts as an efficient steam jacket to the interior vessel. The latter is provided with a water-gauge glass W and a graduated scale S.



The sample of steam, whose

quality is to be determined, is supplied through the pipe P. The water and steam entering the instrument strikes against the lower part of the cup C, and is then deflected upward through an angle of nearly one hundred and eighty degrees, and the water is forced or splashed out, through the meshes in the cup, into the lower part of the chamber F, the steam passing upward and entering the top of the outside chamber E. It then passes downward and leaves the instrument as dry, saturated steam, through an orifice O of known sectional area. This orifice is much smaller than any section of the passages through

the calorimeter, so that the steam in the outer chamber suffers no sensible reduction in pressure while passing through the calorimeter. Now, as the pressure in the outer chamber is the same as that in the inner chamber, the temperature is the same, and consequently, no loss by radiation takes place from the inner chamber, except at the gauge glass; and this latter, as determined by experiment, is so small as not to sensibly effect the result.

A pressure gauge G is attached to the top of the outer chamber, and indicates the pressure of the steam in the same. This is provided with a scale showing the flow of steam through

the instrument. It is the outer one on the dial and is graduated by trial, giving the weight of steam (in lbs.) passing through the calorimeter in an interval of ten minutes. This weight may be approximately determined by use of the formula

$$W = \frac{p_1 a}{70}$$

in which W is the weight of steam discharged through the orifice in pounds per second; a is the area of the orifice in square inches, and p_1 is the absolute steam pressure, in pounds per square inch, which is equal to, or greater than, one and two-thirds that of the atmosphere.

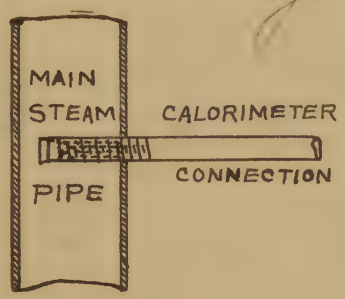
This formula is derived from Napier's Law, which states that "the

flow of steam through an orifice, from a higher to a lower pressure, is proportional to the area of the orifice, and to the absolute steam pressure, until the pressure against which the flow takes place equals or exceeds six-tenths of that in the vessel under pressure.

The water separated from the steam is shown by means of the scale S and the index I on the gauge glass, and is given in pounds and hundredths. The percentage of moisture in the steam is then found by dividing the weight of water, as shown on the water gauge S, by the sum of this quantity and that on the flow gauge H. The quality of the steam is then given by the difference

between this percentage and the total percentage (100).

Now in order that the sample of steam to be tested should represent as nearly as possible the entire quantity of steam supplied to the engine, the Calorimeter should be located as close to the engine as possible, and the connection with the steam pipe should be made as shown in the sketch.



Half inch pipe is generally used for this purpose. It is screwed into the main pipe three quarters the distance through and is provided with side perforations and a plug, screwed into its end.

From experiments it is shown that the quality of the steam dif-

fers greatly in different portions of the same pipe, and more in horizontal than in vertical pipes. The steam in contact with the sides contains more than the average amount of moisture, and by the old method of connecting the calorimeter to the main steam pipe the steam tested was not the steam used by the engine, but only the more moist part of the same.

Description of the Engine.

The machine upon which the test was made was an eight horse-power Case Automatic High Speed Engine, made by the J. I. Case Engine Company of Connecticut, connected directly to a 4½ K.W. Crocker-Wheeler compound wound dynamo, manufactured by the Crocker-Wheeler Electric Company of New York.

The Case Engine belongs to the class known as oscillating engines in which the connecting-rod is suppressed and the piston-rod is connected directly to the crank-pin. As the piston travels back and forth through the cylinder the latter by reason of its shape rocks back-ward and foward in its casing thus

providing for the motion of the crank-pin in a horizontal direction.

A very long stuffing-box connection is used to give leverage to the cylinder and the rocking motion of the latter is sufficient to open and close the steam and exhaust ports in its seat. The upper end of the cylinder is open so that the steam which has entered for the downward stroke acts between the piston head and the cylinder casing and as the lower end of the cylinder is closed this pressure forces the cylinder down against its seat and causes excessive friction. The latter is reduced to a minimum by means of what is termed by the makers a "Balancing Chamber".

This is a small chamber

formed by hollowing out a portion of the lower part of the cylinder so that the area of the cylinder casing forming one boundary is equal to that of the piston. Passages leading from the ports provide for the admission of steam to the chamber. The slight wear that does occur between the cylinder and its casing is taken up by two taper pins which expand the cylinder to make it tight.

The casing surrounding the cylinder is chambered out and while the engine is running is filled with live steam thus forming an effective steam jacket.

The cut-off valve is of the plug type and is tapered so that it can always be kept tight upon

its seat by means of a set-screw at the end. Its only office is to define the point of cut-off; the admission, release, and closing of the exhaust being controlled by the motion of the cylinder.

The frame of the engine protects the principal moving parts from mechanical injury and dirt.

The lower part of the casing is filled with oil and water for the purpose of lubricating the crank pin and main bearings of the engine. The crank pin dips into the oil at every revolution and the oil for the main bearings is carried around by pockets in the crank disc. Any excess which finds its way out on the shaft is thrown off by centrifugal action

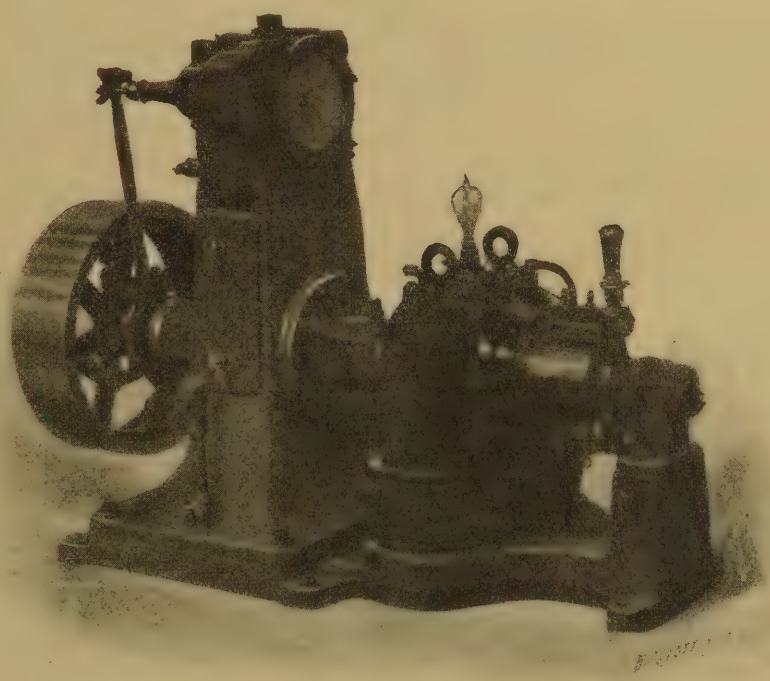
from ring wipers, and flows through a separate passage back into the reservoir. The oil and water finds its way through small openings to a settling chamber below the reservoir and being away from the churning action of the crank the oil separates and returns to the upper case. Access to the interior of the casing may be had through openings on either side by turning the hand screws and removing the plates.

The cylinder was lubricated by a sight feed lubricator.

A shaft governor controlled by centrifugal action rotates the eccentric on the shaft thus giving the valve the right amount of lead over the crank. This governor

does not diminish the throw of the valve and so throttle the steam on light loads but the valve has always the same amount of travel.

This engine, owing to its high rotative speed and good governing is well adapted to the driving of dynamos directly.



Description of the Dynamo.

The dynamo has a drum wound armature having fifty-six coils of six wires in parallel, the core being bored out around its circumference to receive them.

The field magnets are of the overtype form and are constructed of wrought iron, the yoke being formed by a thin wrought iron plate about three-eighths of an inch thick bolted to the cast iron base. The current is collected by means of four carbon brushes.

A self-oiling and self-aligning bearing is used for the commutator end of the shaft. This bearing carries a loose ring

at each end which rests upon the shaft and is free to revolve with it. The lower part of each dips into a reservoir of oil, and as they are driven around a continual supply of oil is fed to the shaft.

The Test.

The test was conducted on the ground floor of the Mechanical Engineering Department of the University of Pennsylvania.

The object was to determine the water consumed per kilo watt-hour.

For the purpose of comparison with other engines, the water consumed per indicated horsepower hour is also generally stated; but as no indicator cards were taken this could not be determined.

The water was determined by condensing the exhaust from the engine in a surface condenser and weighing in a large, iron

tank. It was conveyed from the condenser to the tank by means of buckets.

The condensing water was supplied from a tank in the fourth floor of the building. This was run through the condenser into a lower, cement-lined tank, from which it was again pumped into the upper tank and the same water used over again. After a time it became so warm that steam instead of water issued from the condenser. This was then run into the sewer, and replaced by cold water from the city mains.

The quality of the steam was determined from a sample drawn from the vertical steam pipe,

near the engine. Instead of noting the amount of water separated from the sample of steam in ten minutes from the scale, the time taken for a certain amount, represented by a number of whole divisions on the scale, to separate, was noted, and from this the amount separated in ten minutes determined. In this way the reading of a fraction of a division on the scale is avoided, and the time is noted in seconds, which is much more accurate.

The speed was taken with a Starrett's Hand Speed Indicator for one half minute, and doubled.

The ammeters used were only made to read as high as

twenty-five amperes, and as the maximum current flowing was thirty-five amperes, the parallel arrangement had to be adopted for the higher loads. For the lower loads one ammeter was placed in series.

An oil barrel filled with water, and provided with two electrodes (iron plates) connected to the terminals of the machine, through the ammeters and switch, formed the external circuit. The upper electrode was made adjustable, so that the current could be kept constant.

For the higher loads the resistance of the water had to be reduced by the addition of some salt to it.

The pressure of the brushes upon the commutator was made just sufficient to overcome the ordinary vibration due to the rotation of the armature, and to prevent sparking when collecting the full current.

Before starting the test a preliminary run was made to see if the connections were all correct.

After running for a short time the commutator became heated up, due probably to short-circuits being formed by the carbon dust lodging between the segments. The trouble was soon remedied, however, by cleaning with a piece of sand paper.

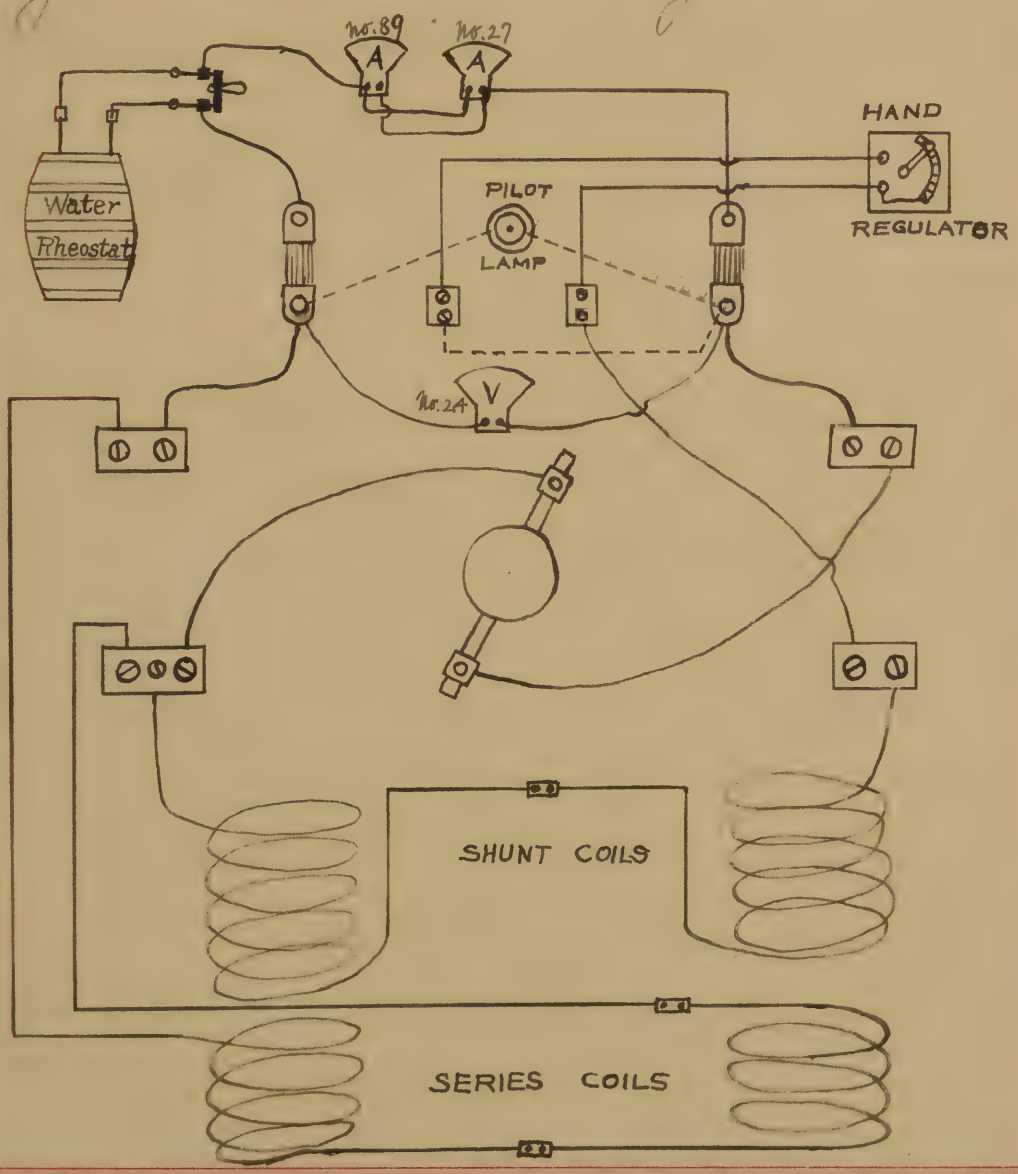
Getting Ready for the Test.

A Carpenter's Separating Calorimeter was attached to the vertical steam pipe, about eighteen inches above the top of the engine. The pilot lamp was removed from the dynamo, and the hand regulator connected in series with the shunt field circuit. A voltmeter was connected across the terminals of the machine, and two ammeters, in parallel, were placed in series with the water rheostat and double pole switch, in the external circuit.

The brushes were then bedded upon the commutator and given the right amount of pressure, after which the oil cups

were filled, when the engine was ready for running.

In the diagram of electrical connections ammeters are denoted by A and voltmeters by V.



Starting the Engine.

Before starting the engine the exhaust valve and petcock between the cylinder and exhaust pipe were opened; a bucket was placed under the condenser, and the circulation of water through the latter started.

Then, with the external circuit open, and all of the resistance coils cut out of circuit, the fly-wheel of the engine was turned, in the direction of motion, far enough to open the ports and form a leverage for the steam to turn the crank.

This done, the throttle valve was opened slowly, thus letting steam into the cylinder.

After a few strokes of the engine the pet cock was closed.

The object in opening this cock was to allow the steam, which had condensed in the cylinder since the last running of the engine, to escape.

The sight feed lubricator was then adjusted to feed an ample supply of oil to the cylinder. The amount of oil required for the bearings depends upon the load, and the nature of the oil used.

The engine was carefully brought up to full speed, and the resistance coils gradually cut in as the voltage increased. When the latter became steady at one hundred and ten volts, the

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switch was closed, and the load being increased the required amount, the voltage was readjusted and the output kept constant throughout the test. The brushes were then given the proper amount of lead and clamped in position.

Steam was permitted to blow through the calorimeter until it was thoroughly heated, before any determinations were made.

The test was started by noting the time, and taking the weight of the tank, an empty bucket being placed under the condenser.

The calorimeter was then started at the lower mark and the time in hours, minutes and seconds noted, together with the

initial pressure. When the water in the calorimeter reached the upper mark the time and pressure were again noted.

The speed was taken every five minutes, ~~and~~ the weight of the tank every ten minutes, and the calorimeter observations as often as practicable during the hour, the voltage and current being kept constant.

Seven one-hour tests were run with different loads, and the results tabulated. The tabulated values are the true values, after allowing for errors in the instruments. Correction for press. was applied to the average.

When shutting down the machine the load was first gradually reduced by throttling the

steam, and when the current was reduced to a small amount, the external circuit was opened. This was done to reduce the sparking at the switch contacts.

Calibration of Instruments

Steam Gauge.— The steam gauge was calibrated by comparison, with a Crosby Gauge Tester. This consists of a channel filled with oil, or glycerine, and provided at one end with a piston. To the other end is attached the gauge to be tested, and below this is a cock. Now, if weights be placed upon the piston and the cock leading to the gauge opened slowly, the pointer will gradually move to the division upon the graduated face of the pressure gauge, corresponding to the pressure exerted by the weights upon the oil.

There is a little friction, due to the motion of the piston

up and down, but this can be almost entirely gotten rid of by spinning the piston around just before opening the gauge cock.

The area of the lower end of the piston was one quarter of a square inch. The weight of the piston itself was one and a quarter pounds, and the pressure per sq in exerted by it was therefore five pounds.

The weights used were: one weighing one and a quarter pounds, one weighing two and a half pounds, and the rest each weighing five pounds. When placed upon the piston they produced pressures of ten, fifteen and twenty-five pounds per square inch respectively (taking into consideration the weight of the

piston).

The gauge calibrated was only corrected for pressures used throughout the test. Readings were taken while the pressure was gradually increased, and while it was gradually decreased. The correction to be applied was the mean of these two readings

Ammeters and Voltmeters.- There was no correction for the voltmeter, but the ammeters were both found to read a few divisions high.

The scales and Calorimeter were correct.

Calibration of Steam Gauge with Crosby Gauge Tester.

Make of Gauge - - - - - - - - Schaeffer & Budenberg
Number " " - - - - - - - - - - - - - - - - 2079755

June 6, 1899

Number of Observation	Gauge Reading up lbs. per sq in.	Gauge Reading down lbs. per sq in.	Actual Pressure lbs. per sq in.	Correction lbs. per sq in.
1	92.	92.	80	-12.
2	97.	97.	85	-12.
3	102.5	102.5	90	-12.5
4	105.	106.	95	-10.5
5	111.	112.	100	-11.5

Constants of Engine.

Type of Engine		Vertical Automatic High Speed
Make " "		J. I. Case Engine Co.
No. " "		4
Nominal Speed (rev. per min.)		650
Rated Horse power (at 80 lbs. pres.)		8
Size of Cylinder		4" x 4"
Diam. of Piston-rod		1"
Diam. of Crank-pin		$1\frac{5}{8}$"
Length " " "		$3\frac{1}{4}$"
Mean diam. of Valve		2"
Travel of Valve		1"
Area of Piston	Head End	12.6 sq. in.
	Crank "	11.8 " "
Piston Displacement	Head End	50.4 cu. in.
	Crank "	47.2 " "
Diam. of Fly-Wheel		18"
Face " " "		$5\frac{1}{2}$"
Diam. of Steam pipe		$1\frac{1}{4}$"

Diam. of Exhaust Pipe	$1\frac{1}{2}$"
Bed Plate of Engine	17"×24"

Constants of Dynamo

Type of Dynamo	Compd Wound (D.C)
Make " "	Crocker-Wheeler Elect. Co.
Number " "	26
Rating in Volts	125
" " Amperes	35
" " Kilowatts	$4\frac{1}{2}$
Nominal Speed of Armature (revs. per min.)	650
Diam. of Armature (body)	10"
Length " " (")	$9\frac{1}{2}$"
Diam. " " (Core)	10"
Length " " (")	6"
No. of Segments on Commutator	56

Calorimeter

June 5, 1899 — Load No. 1

Time at Mark hrs - min - secs	Mark	Press.	Time at Mark hrs. min. secs	Mark	Press.	Time elapsed hrs. min. secs
11.39.25	0	102	11.45.10	10	98	5.45
11.45.10	10	98	11.50.00	20	101	4.50
11.53.00	0	102	11.59.30	10	103	6.30
11.59.30	10	103	12.05.35	20	105	6.05
12.10.10	0	106	12.16.30	10	108	6.20
12.16.30	10	108	12.22.35	20	107	6.05
12.25.55	0	108	12.32.10	10	107	6.15
12.32.10	10	107	12.38.20	20	106	6.10
Means		104.2			104.4	6.00

Mean pressure - 104.3
Correction - -11.3

True pressure - 93.

Wt. of Steam discharged in 10 min. = 4.34 lbs.

General Readings.

June 5, 1899 — Load No. 1

Time	Volts No. 24	Amps. No. 89	Amps No. 27	Speed	Wt. of Tank	Remarks.
11.40	110	19.3	15.7	—	725	Ammeter No. 89
11.45	110	19.3	15.7	564		read .4 amp. too
11.50	110	19.3	15.7	548	788	high.
11.55	110	19.3	15.7	552		Ammeter No. 27
12.00	110	19.3	15.7	596	848	read .1 amp. too
12.05	110	19.3	15.7	580		high.
12.10	110	19.3	15.7	596	908	Voltmeter correct
12.15	110	19.3	15.7	592		Started with
12.20	110	19.3	15.7	596	967	cold water
12.25	110	19.3	15.7	598		in upper
12.30	110	19.3	15.7	588	1024	tank.
12.35	110	19.3	15.7	594		
12.40	110	19.3	15.7	580	1084	
Means.	110	19.3	15.7	582		

Calorimeter.

June 3, 1899 Load No. 2

Time at Mark hrs. min. secs.	Mark	Press.	Time at Mark hrs. min. secs.	Mark	Press.	Time Elapsed hrs. min. secs.
1.38.00	0	104	1.42.25	10	105	4.25
1.42.25	10	105	1.46.50	20	106	4.25
1.49.00	0	105	1.53.45	10	106	4.45
1.53.45	10	106	1.58.25	20	102	4.40
2.01.55	0	100	2.05.40	10	98	3.45
2.05.40	10	98	2.09.05	20	100	3.25
2.12.15	0	100	2.16.35	10	102	4.20
2.16.35	10	102	2.20.25	20	103	3.50
2.24.15	0	101	2.27.50	10	100	3.35
2.27.50	10	100	2.31.55	20	100	4.05
2.34.45	0	98	2.38.45	10	96	4.00
Means		101.8			101.6	4.07

Mean Press. 101.7

Correction − 12.4

True Press. 89.3

Wt. of Steam Discharged in 10 min. = 4.17 lbs.

General Readings.

June 3, 1899 — Load No. 2

Time	No. 34 Volts	No. 89 Amps.	No. 27 Amps.	Speed	Wt. of Tank	Remarks.
1.40	110	16.5	13.5	602	688	Ammeter No. 89
1.45	110	16.5	13.5	606		read .4 amp. too high.
1.50	110	16.5	13.5	605	744	Ammeter No. 27
1.55	110	16.5	13.5	605		read .1 amp. too
2.00	110	16.5	13.5	599	797	high.
2.05	110	16.5	13.5	603		Voltmeter cor-
2.10	110	16.5	13.5	600	855	rect.
2.15	110	16.5	13.5	600		
2.20	110	16.5	13.5	604	—	
2.25	110	16.5	13.5	604		
2.30	110	16.5	13.5	602	959	
2.35	110	16.5	13.5	598		
2.40	110	16.5	13.5	597	1008	
Means	110	16.5	13.5	602		

Calorimeter.

June 3, 1899 — Load No. 3

Time at Mark hrs. min. secs.	Mark	Press.	Time at Mark hrs. min. secs.	Mark	Press.	Time Elapsed hrs. min. sec.
3.54.00	8	97	3.58.04	18	98	4.04
3.59.45	0	97	4.03.53	10	97	4.08
4.03.53	10	97	4.07.35	20	97	3.42
4.08.38	0	98	4.12.35	10	97	3.57
4.12.35	10	97	4.16.22	20	98	3.47
4.18.35	2	99	4.22.14	12	101	3.39
4.22.14	12	101	4.26.35	22	100	4.21
4.27.50	0	103	4.32.30	10	103	4.40
4.32.30	10	103	4.37.30	20	104	5.00
4.38.38	0	103	4.43.28	10	104	4.50
4.43.28	10	104	4.47.58	20	103	4.30
4.49.38	0	103	4.54.22	10	103	4.44
Means.		100.2			100.4	4.17

Mean Press. 100.3

Correction −12.3

True Press. 88.

Steam Discharged in 10 min. = 4.13 lbs.

General Readings.

June 3, 1899 — Load No. 3

Time	No. 24 Volts	No. 89 Amps	No. 27 Amps.	Speed	Wt. of Tank	Remarks
3.55	110	13.9	11.1	604	715	Ammeter No. 89
4.00	110	13.9	11.1	612		read .4 Amp. too
4.05	110	13.9	11.1	605	765	high.
4.10	110	13.9	11.1	616		Ammeter No. 27
4.15	110	13.9	11.1	598	812	read .1 amp. too
4.20	110	13.9	11.1	606		high.
4.25	110	13.9	11.1	614	859	Voltmeter cor-
4.30	110	13.9	11.1	612		rect.
4.35	110	13.9	11.1	610	906	Condensing water
4.40	110	13.9	11.1	612		getting warm.
4.45	110	13.9	11.1	618	952	
4.50	110	13.9	11.1	606		
4.55	110	13.9	11.1	618	998	
Means	110	13.9	11.1	610		

Calorimeter

June 3, 1899 — Load No. 4

Time at Mark hrs. min. secs.	Mark	Press.	Time at Mark hrs. min. secs.	Mark	Press.	Time Elapsed hrs min sec.
5. 03.15	0	102	5. 06.52	10	105	3.37
5. 06.52	10	105	5. 10.05	20	105	4.13
5. 11.30	0	100	5. 14.50	10	100	3.20
5. 14.50	10	100	5. 18.05	20	102	3.15
5. 19.20	0	103	5. 22.43	10	103	3.23
5. 22.43	10	103	5. 26.18	20	103	3.35
5. 27.47	0	104	5. 31.20	10	103	3.33
5. 31.20	10	103	5. 35.10	20	103	3.50
5. 36.50	0	102	5. 40.08	10	102	3.18
5. 40.08	10	102	5. 43.33	20	103	3.25
5. 44.55	0	103	5. 48.25	10	103	3.30
5. 48.25	10	103	5. 52.04	20	103	3.39
5. 53.25	0	104	5. 56.50	10	102	3.25
5. 56.50	10	102	6. 01.00	20	102	4.10
Means		102.6			102.8	3.35

Mean Press. 102.7

Correction −12.4

True Press. 90.3

Steam discharged in 10 min. = 4.22 lbs.

General Readings.

June 3, 1899 — Load No. 4

Time	No. 24 Volts	No. 89 Amps.	No. 27 Amps.	Speed	Wt. of Tank	Remarks.
5.05	110	11.1	8.9	608	886	ammeter No. 89
5.10	110	11.1	8.9	612		read 4 amp. too
5.15	110	11.1	8.9	620	928	high.
5.20	110	11.1	8.9	612		ammeter No. 27
5.25	110	11.1	8.9	608	970	read .1 amp. too
5.30	110	11.1	8.9	608	1011	high.
5.35	110	11.1	8.9	608	1011	Voltmeter cor-
5.40	110	11.1	8.9	610		rect.
5.45	110	11.1	8.9	608	1053	condensing
5.50	110	11.1	8.9	610		water very
5.55	110	11.1	8.9	608	1095	warm
6.00	110	11.1	8.9	612		
6.05	110	11.1	8.9	612	1135	
Means	110	11.1	8.9	610		

Calorimeter.

June 5, 1899 — Load No. 5

Time at Mark hrs. min. secs.	Mark	Press.	Time at Mark hrs. min. secs.	Mark	Press.	Time Elapsed hrs. min. secs.
3. 55.43	0	100	3. 58.07	20	101	2. 24
3. 59.55	0	100	4. 02.18	20	100	2. 23
4. 03.33	0	100	4. 05.58	20	100	2. 25
4. 06.41	0	100	4. 09.09	20	100	2. 28
4. 11.57	0	100	4. 14.25	20	100	2. 28
4. 15.15	0	100	4. 17.38	20	100	2. 23
4. 18.30	0	100	4. 20.53	20	101	2. 23
4. 21.37	0	100	4. 23.58	20	101	2. 21
4. 24.47	0	100	4. 27.09	20	101	2. 22
4. 28.05	0	101	4. 30.26	20	101	2. 21
4. 31.27	0	101	4. 33.43	20	101	2. 16
4. 34.28	0	101	4. 36.48	20	101	2. 20
4. 37.30	0	101	4. 40.07	20	101	2. 23
4. 42.00	0	101	4. 44.21	20	101	2. 21
4. 45.25	0	101	4. 47.47	20	101	2. 22
4. 49.04	0	101	4. 51.27	20	101	2. 23
4. 52.43	0	101	4. 55.05	20	100	2. 22
Means		100.5			100.6	2. 23

Mean Press. 100.6
Correction −12.3
True Press. 88.3

Steam discharged in 10 min. = 4.14 lbs.

General Readings.

June 5, 1899 — Load No. 5

Time	No. 24 Volts	No. 89 Amps.	Speed	Wt. of Tank	Remarks.
3.55	110	15	612	929	Ammeter No. 89
4.00	110	15	620		read 4 amp. too high
4.05	110	15	620	969	Voltmeter correct.
4.10	110	15	602		Started to pump
4.15	110	15	608	1007	the warm condensing
4.20	110	15	606		water into the upper
4.25	110	15	600	1045	tank at 4.05
4.30	110	15	612		Steam began issuing
4.35	110	15	618	1083	from condenser
4.40	110	15	610		at 4.20
4.45	110	15	612	1121	
4.50	110	15	606		
4.55	110	15	620	1160	
Means	110	15	611		

Calorimeter

June 5, 1899 — Load No. 6

Time at Mark hrs. min. secs.	Mark	Press.	Time at Mark hrs. min. secs.	Mark	Press.	Time Elapsed hrs. min. secs.
2.43.56	0	104	2.46.42	20	102	2.46
2.49.22	0	101	2.52.10	20	100	2.48
2.54.12	0	98	2.56.57	20	98	2.45
2.59.00	0	96	3.01.49	20	101	2.49
3.03.50	0	100	3.06.31	20	100	2.41
3.09.37	1	100	3.12.22	21	100	2.45
3.13.15	1	100	3.16.00	21	100	2.45
3.17.54	0	100	3.20.37	20	100	2.43
3.22.23	0	101	3.24.58	20	101	2.35
3.26.37	0	101	3.29.17	20	101	2.40
3.32.34	0	102	3.35.08	20	102	2.34
3.38.15	1	102	3.41.00	21	103	2.45
3.42.32	0	103	3.45.21	20	102	2.49
Means		100.6			100.8	2.43

Mean Press. 100.7

Correction −12.3

True Press. 88.4

Steam discharged in 10 min. = 4.15 lbs.

General Readings.

June 5, 1899 — Load No. 6

Time	No. 24 Volts	No. 89 Amps.	Speed	Wt. of Tank	Remarks.
2.45	110	10	608	720	Ammeter No. 89
2.50	110	10	610		read 4 amp. too
2.55	110	10	610	755	high.
3.00	110	10	612		Ammeter No. 27
3.05	110	10	612	790	read .1 amp. too
3.10	110	10	614		high.
3.15	110	10	596	825	Voltmeter correct.
3.20	110	10	604		
3.25	110	10	618	859	
3.30	110	10	616		
3.35	110	10	618	894	
3.40	110	10	608		
3.45	110	10	628	930	
Means	110	10	612		

Calorimeter.

June 5, 1899 — Load No. 7

Time at Mark hrs. min. secs.	Mark	Press.	Time at Mark hrs. min. secs.	Mark	Press.	Time Elapsed hrs. min. secs.
1.30.05	0	105	1.33.55	20	104	3.50
1.35.24	0	103	1.39.00	20	102	3.36
1.39.58	0	102	1.43.52	20	100	3.54
1.45.35	2	98	1.49.17	22	98	3.42
1.50.10	0	97	1.54.12	20	96	4.02
1.56.15	0	95	1.59.52	20	95	3.37
2.01.45	0	94	2.05.30	20	93	3.45
2.06.15	0	92	2.09.55	20	93	3.40
2.12.20	3	97	2.15.40	23	103	3.20
2.18.04	0	104	2.22.00	20	101	3.56
2.23.32	0	100	2.27.22	20	100	3.50
2.29.08	0	102	2.32.42	20	105	3.34
Means		99.1			99.2	3.44

Mean Press. 99.2

Correction -12.2

True Press. 87.

Steam Discharged in 10 min. = 4.03 lbs.

General Readings.

June 5, 1899 — Load No. 7

Time	No. 24 Volts	No. 89 Amps.	Speed	Wt. of Tank	Remarks.
1.35	110	5.	624	1099	Ammeter No. 89
1.40	110	5	626		read .4 too high
1.45	110	5	612	1132	Voltmeter correct.
1.50	110	5	616		
1.55	110	5	616	1162	
2.00	110	5	620		
2.05	110	5	624	1192	
2.10	110	5	616		
2.15	110	5	618	1222	
2.20	110	5	606		
2.25	110	5	614	1254	
2.30	110	5	610		
2.35	110	5	616	1285	
Means	110	5	617		

Results.

In the following table the average results are given for each load. From the foregoing readings the average results were calculated for each run, and noted in the table of final results.

The calculations for one set of values is given below for the first load; those for the other loads being performed in the same manner.

In the first place, the power expended in kilowatts is (See General Readings)

$$\frac{110 \times 35}{1000} = 3.85$$

Turning to the calorimeter readings for this load, we see

that the corrected average pressure is 93 lbs. per sq in. From the steam gauge, the weight of steam passing through the calorimeter in ten minutes, corresponding to this pressure, is given as 4.34 lbs.

Now one small division on the scale 25, of the calorimeter, corresponds to one hundredth of a pound of moisture. The time elapsed while ten divisions were traversed was found to be 6 minutes. The the weight of water caught in one minute is

$$\frac{10 \times .01}{6} \text{ lbs.}$$

and that caught in 10 minutes is

$$\frac{10 \times .01}{6} \times 10 = .167 \text{ lb.}$$

from which the quality of steam (x)

is expressed as

$$\frac{4.34}{4.34 + .167} = .962$$

Under the head of "General Readings" for the same load we see that at the beginning of the run the tank weighed 725 lbs. and at the end the weight was 1084 lbs., so that

$$1084 - 725 = 359 \text{ lbs.}$$

of steam were used.

From Thermodynamics, the weight of dry saturated steam equivalent to this is

$$W = \frac{359(q_{107.7} + x\, r_{93+14.7})}{q_{93+14.7} + r_{93+14.7}}$$

and substituting the values from the steam tables we have

$$W = \frac{359(303.8 + .962 \times 879.8)}{303.8 + 879.8}$$

$$= 349 \text{ lbs.}$$

Wt. of Steam per KW. hr. (actual)

$$\frac{359}{3.85} = 93.4$$

Equivalent Wt of dry Steam per KW. hr.

$$\frac{349}{3.85} = 90.6$$

Wt. of Steam per Electrical Horsepower hr. (actual)

$$\frac{359 \times 746}{3850} = 69.7$$

Equivalent Wt. of dry Steam per E.H.P. hr.

$$\frac{349 \times 746}{3850} = 67.8$$

Wt of Steam per rev. (actual)

$$\frac{359}{582} = .617$$

Equivalent Wt. of Dry Steam per rev.

$$\frac{349}{582} = .600$$

Observed Data.
(Averages).

Load (Amps.)	Power Expended (Kilowatts)	Steam Pressure (lbs. per sq. in.)	Rev. per min.	Quality of Steam (x)	Wt. of Condensed Steam (Total) (lbs.)	Equivalent Wt. of Fully Steam (lbs.)	Wt. of Steam per Kilowatt hr. (actual) (lbs.)	Equivalent Wt. of Fully Steam per K.W. hr. (lbs.)	Wt. of Steam per E.H.P. hr. (actual) (lbs.)	Equivalent Wt. of Fully Steam per E.H.P. hr. (lbs.)	Wt. of Steam per rev. (actual) lbs.	Equivalent Wt. of Fully Steam per rev. (lbs.)
35	3.85	93.0	582	.962	359	349	93.4	90.6	69.7	67.8	.617	.600
30	3.30	89.3	602	.947	320	307	96.9	93.0	72.3	69.4	.531	.509
25	2.75	88.0	610	.949	283	272	103.0	99.1	77.0	74.0	.465	.447
20	2.20	90.3	610	.938	249	238	113.3	108.5	84.6	81.0	.408	.391
15	1.65	88.3	611	.832	231	202	140.3	122.5	104.8	91.5	.378	.330
10	1.10	88.4	612	.850	210	186	191.0	169.5	142.7	126.5	.343	.304
5	.55	87.0	617	.882	186	169	339.0	307.5	253.0	229.5	.302	.274

Conclusions.

From the results it will be seen that the speed for the higher loads varied somewhat, while those for the lower loads were practically constant. This was probably due to the governor, and possibly some of the working parts were not exactly in the line of action, thus causing side friction

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N/1198/03073/2601X

3 1198 03073 2601
N/1198/03073/2601X